READING DISABILITY:
A NEUROPSYCHOLOGICAL INVESTIGATION

By

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INTRODUCTION

The failure of apparently normal children to learn to read is currently an active area of investigation and dispute in psychology and related disciplines. The child who has the necessary intelligence and motivation to master the skills of reading acquisition, and yet fails to do so, presents a perplexing problem. The professional as well as the popular literature is replete with publications attempting to explain the syndrome and its etiology.

As early as 1896, Morgan described a constitutionally based reading problem which he called "congenital word blindness." He attributed the disorder to a defect in the angular gyrus, and thus gave impetus to future investigators who looked for a subtle but basically constitutional etiology for reading disorders. Such a view point was not readily accepted, however, and one must view the "Zeitgeist" of the early 1900's to appreciate the lack of impact of the constitutionalist's view. The social sciences were polarizing toward the nurture end of the nature-nurture controversy, and constitutional factors were deemphasized as explanations of behavior. In recent years, however, the emphasis has shifted, resulting in an increased interest in examining constitutional factors underlying many behaviors, including reading disability.

Of the constitutional factors which may underlie retarded reading, minimal brain damage has been frequently proposed. Money

(1966), however, finds the minimal brain damage hypothesis untenable and concludes:

> By far the most useful hypothesis, in this matter of brain function and reading disability, is not a quasineurological one at all, but a neuropsychological one of maturational lag. Then it can be allowed that some cases of maturational lag in reading may be a sequel to known, demonstrable brain pathology, even though disability specific to reading is rare in cases of brain pathology in childhood. The great majority of reading disability cases will be classifiable not on the basis of brain pathology, but simply as representative of a lag in the functional development of the brain and nervous system that subserves the learning of reading. (p. 34)

Therefore, Money (1966) and other investigators have examined other neuropsychological variables in an attempt to understand the basis of reading disability. Unfortunately, a lack of theory and poor methodology, coupled with investigation of isolated dimensions in reading disability, makes a systematic review of the problem difficult.

Laterality and Its Dimensions

Of particular interest has been the problem of laterality. Although the meaning of laterality among investigators is unclear, implicit in the research is the concept of left-and-right or "sidedness." The laterality variable seems to be the common factor underlying the symptom complex found in the intellectually normal child with reading difficulties. Typical problems include reversals, transpositions, mirror writing and rotations, all involving a left-right dimension. In addition, the high incidence of both reading problems and left-handedness among boys (Bentzen, 1963) has led to the examination of the relationship between the two phenomena.

Besides the more peripheral, sensorimotor phenomena of mixed, incomplete or confused hand preference (manual laterality), and eye preference (visual laterality). (Orton, 1937; Harris, 1957; Naidoo, 1961; Zangwill, 1962), studies of laterality have focused upon a second aspect, that of more central mechanisms which belong primarily in the perceptual-cognitive sphere. The perceptual-cognitive area includes problems in left-right awareness, spatial awareness (Rabinovitz, Drew, DeJong, Ingram, & Withey, 1954; Harris, 1957; Hermann & Norrie, 1958; Kinsbourne & Warrington, 1963; Belmont & Birch, 1965), and verbal intelligence (Rabinovitz et al., 1954; Belmont & Birch, 1966).

Manual and Visual Laterality

The first laterality category (manual and visual laterality) includes the classical work of Orton (1937) who suggested that mixed hand dominance was an important factor in reading disability. Dearborn (1933) and Monroe (1932) found similar results in their investigations. However, Bennet (1938) and Johnston (1942) found no relationship between mixed hand dominance and reading problems. Harris (1957) ascribed this lack of concensus to the use of inappropriate testing procedures. Therefore, he developed an extensive battery (including hand, eye and foot) for studying mixed laterality. His investigation of 316 cases of severe reading problems demonstrated a significant degree of mixed and confused laterality. Naidoo (1961), although not primarily concerned with reading problems, found that children with "ambiguous handedness" showed deficits in verbal skills. On the other hand, Belmont and Birch (1965) found no differences between their experimental

and control groups in terms of mixed or incomplete manual and visual laterality. In addition, Belmont and Birch (1965) have leveled a series of criticisms against most of the work relating laterality to reading disability:

> The samples studied have frequently been drawn from clinic populations with unknown selection biases; I.Q. has been either unknown or unreported; and age and sex ratios have varied. Differences in findings, therefore, may derive equally as readily from differences in the samples studied as from correct or incorrect attributions of an association among the phenomena of lateral preference, lateral awareness, and reading disability. (p. 58)

Palmer (1964) also expressed reservations about manual laterality research. His review of the literature revealed that there has been a strong tendency to rely on questionnaires as measures of handedness and to exclude measures of manual proficiency (e.g., dexterity). He concludes, "One must ask if consistent preferences necessarily signify a strong unimanual proficiency" (p. 261). That they do not was supported by the work by Satz, Achenbach, and Fennell (1967), who found low correlations between tests of proficiency and self-classified manual preference, particularly for self-classified left-handers.

Another confounding issue in the area of manual laterality is the reported high incidence of left-handedness among retarded readers and also members of their families (Zangwill, 1962; Money, 1966). Hallgren (1950), in examining the families of 112 retarded readers, however, found the incidence of left-handedness relatively low.

In summary, research in manual and visual laterality, as it relates to reading problems, has been inconclusive. Test measures

have relied on subjective reports of hand or visual preference; only isolated variables have been examined; methodology has been weak; and there has been little attempt at conceptualization.

Perceptual-Cognitive Laterality

In the second category of laterality (perceptual-cognitive laterality) the phenomenon of cerebral dominance, or more accurately, hemispheric dominance for speech, is often assumed to be closely related to mixed manual and visual laterality. Thus, mixed laterality in the periphery may reflect failure to lateralize centrally. However, the relationship between handedness and dominance (or speech-brainedness) has been controversial. A major problem has been the determination of cerebral representation of speech in the normal population. For many years the only knowledge of cerebral representation for speech came from patients who, as a result of brain pathology, became aphasic, or were candidates for neurosurgery. Under these circumstances it was possible to determine the hemisphere which was dominant for speech. Generally, observations of these patients supported the hypothesis that there was at least a partial relationship between handedness and speech-brainedness (Bingley, 1958; Zangwill, 1962). This conclusion was based in part, on the high incidence of aphasia ($\geq$ 95%) in right-handed patients with lesions in the left hemisphere compared with the incidence of aphasia ($\geq$ 35%) in left-handers after right-hemisphere lesions (Zangwill, 1962).

In recent years, however, two experimental procedures have provided stronger evidence for the relationship: the intracarotid

sodium amytal test of speech (Wada, 1949), and the dichotic auditory stimulation technique. The results of the Wada test indicated that the vast majority of right-handed patients were left-brained for speech (90-95%), while the proportion of left-brainedness in left-handed patients was significantly smaller (Branch, Milner, & Rasmussen, 1964). Also, about 15 per cent of the left-handed patients had bilateral representation of speech.

Although the results of the Wada test have supported the hypothesis that there is a relationship between handedness and cerebral lateralization for speech, there are disadvantages in the method. The Wada test is not applicable to subjects in the general population because of the risk associated with administration. In addition, the samples may have been biased because the patients were all candidates for neurosurgery.

The dichotic auditory stimulation technique provides an alternative method for determining cerebral lateralization of speech. However, although it is a benign technique, it is less precise than the Wada test. Kimura (1961) found that when different digits were presented simultaneously to both ears, recall was superior for digits presented to the ear contralateral to the dominant hemisphere. Her results were validated on those Ss who were administered the Wada amytal test. Both right- and left-handed patients showed superior recall for digits presented to the right-channel and also were left-brained for speech on the Wada test. Recent studies on normal Ss have revealed a high probability of left-brain speech representation

for right-handers and a somewhat lower probability of left-brain representation for left-handers (Bartz, Satz, Fennell, & Lally, 1967; Bartz, Satz, & Fennell, 1967; Satz, Achenbach, & Fennell, 1967).

Normal children as young as four years old have been studied using the dichotic stimulation technique. They were found to exhibit strong right-ear superiority, suggesting that speech may be lateralized in the left hemisphere even at these ages (Kimura, 1963). However, the results of this study are questionable because different age groups received different treatments, and the statistical analyses were inappropriate. Taylor (1962), using Kimura's normal Ss as controls, found more atypical speech lateralization in boys than in girls. Unfortunately, the nature of this atypical behavior has not been reported. In addition, the data from this study is not available; the author stated that methodological problems render this study unsuitable for publication (personal communication). Thus, although the dichotic listening test shows promise for the study of language laterality in retarded readers, there is currently no available data.

Lateral awareness is another perceptual-cognitive ability which has been examined in relation to reading problems. Harris (1957) reported directional confusion in disabled readers, especially Ss at the seven-year level. Hermann and Norrie (1958) also found problems in left-right awareness in retarded readers. Coleman and Deutsch (1964), however, did not find such differences when IQ was covaried out. Benton and Kemble (1960) also suggested that problems in lateral awareness are artifacts: when IQ is controlled, significant differences disappear.

There are serious methodological problems in some of the above studies. Subject selection and matching frequently were not adequate. The Ss were from clinic populations; many were non-white children from low socioeconomic areas; and the appropriateness of generalizing from such data is questionable. In addition, sex, age, and intelligence have often been inadequately controlled or unreported.

Belmont and Birch (1965) introduced more rigorous controls in their study of reading problems. Subjects with retarded reading (non-clinic setting) showed significantly more errors on lateral awareness than did normal readers. The statistical treatment of their data was weak, however; the analyses were based largely on frequency data rather than on mean scores.

On the spatial awareness dimension, Kinsbourne and Warrington (1963, 1964) developed a test of finger differentiation. This test was designed to measure differentiation of sensory input; an ability needed in discriminating spatial relationships. The patients in their study were retarded readers with VIQ-PIQ discrepancies. The Ss with low PIQs made more errors in spatial discrimination. The study used older Ss and the N was very small. Since the finger differentiation tests have not been widely used to date, more work is needed before the relationship between reading disability and performance on the tests can be evaluated.

Finally, verbal intelligence (WISC, WAIS) has frequently been investigated in reading disability because of the verbal requirements which underscore the reading process. Also, verbal intelligence has

been postulated to represent the highest level of language differentiation and lateralization in man (Penfield & Roberts, 1959). In fact, unilateral damage to the left hemisphere has frequently been associated with alteration in verbal-test intelligence (Milner, 1962; Satz, Richards, & Daniels, 1967).

In recent years, investigators have been interested in the relationship between verbal intelligence and reading disability. Although controls have frequently been unreported, studies have tended to show a depression in WAIS or WISC verbal IQ in retarded readers. This problem has been reviewed by Belmont and Birch (1966). Retarded readers have shown more impairment in verbal IQ than did controls of the same age. Belmont and Birch (1966) concluded that disabled readers may be impaired in broad aspects of language function. They found that their sample of retarded readers had fewer words in their vocabulary store and used more descriptive and fewer categorical definitions of words. Reed (1967) also found depressed VIQs among their sample of older children with retarded reading (CA 9-10). The findings of Graham (1952), Rabinovitz et al. (1954), and Robeck (1963) suggested that VIQ among older readers might be more important for reading achievement than overall intelligence. On the other hand, Kinsbourne and Warrington (1966) reported that the incidence of depressed PIQ occurs as frequently as depressed VIQ. Therefore, the question of depressed VIQ in reading disability is still unsettled.

In summary, the results on the perceptual-cognitive dimensions of laterality remain as inconclusive as those on manual and visual

laterality. Isolated variables have been investigated, with mixed results; methodology has been inadequate; and there has been a general lack of integration.

The Relationship Between Manual Laterality, Visual Laterality, and Perceptual-Cognitive Laterality

The tendency among many investigators has been to ignore the relationships between the various dimensions of laterality. This may result, in part, from the piecemeal approach of studying isolated deficits. Recent studies in experimental neurology, however, have stressed the interaction of these dimensions of laterality in normal development. Semmes, Weinstein, Ghent, and Teuber (1960) and Semmes (1968) have suggested that the cerebral lateralization of speech stems from lateralization of less complex motor and somatosensory functions which precede the lateralization of speech. For example, Semmes (1968) proposed that each of these hierarchal functions are more focally represented within the left cerebral hemisphere in man. She stated that lateralization follows a logical sequence with each higher level dependent on the level preceding it. Hence, motor laterality precedes sensory laterality, which is followed by lateralization of language. Tschirgi (1958) and Mach (1959) supported this position by suggesting that spatial and lateral awareness are dependent on asymmetry in the perceiving system. In addition, Kephart (1960) proposed that the spatial coordinate system must be established through motor activity. Therefore, motor asymmetry must precede the higher level ability to appreciate directionality in space. These formulations stress an underlying relationship among the various dimensions of laterality.

Summary and Problem

The preceding summary of the literature on the relationship between reading disability and laterality has shown the diversity of approaches to the problem. Unfortunately, most of the research was addressed to isolated deficits (e.g., manual preference, lateral awareness or impaired verbal intelligence), methodology has frequently been inadequate, and little attempt at integration has been made. In addition, the manifestations of laterality as they are found in the retarded reader have not been related to each other or to brain maturation and function. Finally, the various aspects of laterality have not been investigated as they change with age. This constellation of problems has tended to produce a plethora of seemingly diverse and contradictory findings.

It seemed to this investigator that despite the limitations of previous research, laterality shows promise as an etiological variable underlying reading problems. However, the piecemeal investigation has not proved adequate, and a more comprehensive approach with improved methodology seemed warranted. Therefore, the purpose of the present study was to see how retarded readers differ from normal readers in the various ways that laterality is manifested. An additional purpose was to investigate the development of laterality as seen across several age levels.

Finally, the vagueness of the term laterality, with its implicit reference to cerebral dominance, has contributed to the diversity of findings. Therefore, in this investigation, laterality included: (1) the sensorimotor aspects of manual preference and visual preference;

and (2) the perceptual-cognitive aspects of lateral awareness, spatial awareness, and language asymmetry. These aspects were operationally defined by the behavioral measures presented in the following section on methods.

METHOD

Subjects

A careful effort was made to avoid the inadequate sampling and matching procedures characteristic of previous research in reading disability (Belmont, & Birch, 1966). Thus, the subjects (Ss) in this study were 80 white male children from the regular classrooms in the public schools in suburban Hamden, Connecticut. None of the children with reading problems were from a clinic population. Forty of the Ss were retarded readers who ranged from 20 per cent to 61 per cent below the appropriate reading level for their age, as measured by the Iowa Test of Basic Skills and Metropolitan Achievement Test. Forty were normal control children with reading scores at or above the expected levels for their age. It should be noted that the particular schools from which this sample was taken had reading levels from .6 to 1.2 years above national norms. Thus, in this community, the reading deficits might seem even more severe. Both the experimental and control groups consisted of ten 9-year-olds, ten 10-year-olds, ten 11-year-olds, and ten 12-year-olds. In addition, each experimental S was matched with a control on social class based on father's occupation (Hollingshead, & Redlich, 1960) and performance I.Q. (Satz, Van De Riet, & Mogel, 1967). No S with a PIQ below 90 was included in the sample. Because of the large verbal component in reading and the unclear relationship between reading and verbal intelligence, VIQ was allowed to vary

as a dependent measure. Thus, in summary, each experimental S was matched with a control on age, sex, race, social class and PIQ. For a summary of sample characteristics see Table 1. Of added importance, is the intactness of the families from which these children came. Ninety-eight per cent of the Ss came from completely intact families (two deceased fathers in the experimental group). Seventy two per cent of the mothers were housewives (29 in the experimental group, 28 in the control group). Also, no children were included in the study who had known neurological impairment or uncorrected visual problems. All Ss were individually screened with a Beltone audiometer and no S with hearing problems was included. Finally, approximately 25 per cent of the experimental children were receiving remedial reading in their school. None of the experimental Ss were receiving counseling from the school social worker.

Procedures

Each S was tested individually on ten measures. In addition, information regarding family history of left handedness was obtained.

In light of the introduction all ten dependent variables were conceptualized as various measures of laterality. Laterality was further differentiated into (1) manual laterality, (2) visual laterality, and (3) perceptual-cognitive laterality.

Manual Laterality

Manual laterality consisted of: (1) self-classified manual preference, (2) manual preference performance, (3) manual strength, and (4) manual dexterity. The following tests were used.

TABLE 1

MEANS AND STANDARD DEVIATIONS OF SUBJECT CHARACTERISTICS

Characteristics		9 year olds		10 year olds		11 year olds		12 year olds	
		E	C	E	C	E	C	E	C
N		10	10	10	10	10	10	10	10
Age	M	9.34	9.31	10.25	10.39	11.25	11.20	12.18	12.24
	SD	.33	.31	.26	.28	.28	.28	.30	.26
PIQ	M	106.10	107.50	101.90	108.00	100.50	101.60	98.70	100.80
	SD	11.14	8.97	6.26	4.66	6.76	7.33	4.74	7.43
Social Class	M	3.9	3.5	3.4	3.2	3.9	3.5	3.7	3.8
	SD	1.20	1.63	1.43	1.55	1.29	1.43	1.34	1.32
Reading	M	.71	1.20	.68	1.20	.66	1.08	.66	1.10
	SD	.10	.14	.10	.26	.10	.10	.10	.14

Self-Classified Manual Preference

The S was asked to reply verbally if he was left- or right-handed.

Manual Preference Performance

A modification of the Harris Scale of Lateral Dominance was used to test manual preference. This scale consisted of 10 behavioral tasks in which the S used either his right or left hand. Left hand scores were subtracted from right hand scores; thus, a plus (+) score indicated right hand superiority.

Manual Strength

A Jaymar dynamometer measured manual strength. Starting with the preferred hand, strength scores for each hand were determined on three trials. Scores were computed on the mean of the three trials. A discrepancy score was also computed subtracting left score from right; again, a plus (+) score indicated right hand superiority.

Manual Dexterity

An electric tapper was used to measure manual dexterity. Starting with the preferred hand, S was instructed to tap the key as quickly as possible for 10 seconds. This was repeated for three trials with each hand. Means for the three trials were computed and a discrepancy score was determined by subtracting left from right.

Visual Laterality

Visual laterality was conceptually divided into two groups: (1) visual preference (monocular), and (2) controlling eye (binocular).

Visual Preference

Three behavioral tasks were used for visual preference: (1) sighting into a kaleidoscope, (2) sighting with a rifle, and (3) lining up the point of a pencil with an object across the room. Discrepancy scores were computed by subtracting left eye preference from right.

Controlling eye

The Keystone telebinocular machine was used to assess distal controlling eye. Test 5 and 6 from the Keystone Telebinocular Survey Tests were used following the procedure of Berner and Berner, (1953). Each S received a score of left, right or neither, depending on which eye, if any, was controlling.

The hole-in-the-mirror test was used to assess proximal controlling eye. The test consisted of a small mirror completely covered with cardboard, except for a hole in the center. The subject was asked to hold the mirror so that he could just see the tip of his nose, while keeping both eyes open. The E then covered one of the S's eyes with a piece of paper. When the controlling eye was covered, S could not see his nose, while it was visible when the non-controlling eye was covered. For this test, S received a score of right or left.

Perceptual-Cognitive Laterality

The variables subsumed under this category are: (1) finger differentiation, (2) lateral awareness, (3) speech-brain laterality, and (4) VIQ.

Finger differentiation

Tests developed by Kinsbourne and Warrington (1963) were used and included tasks which required the ability to (a) differentiate between one or two fingers being touched, (b) designate the number of fingers between touched fingers, (c) discriminate between various wooden shaped blocks by touch, and (d) recognize by sight the blocks which the S had held in his hand. Scores on these tasks represent number of errors.

Lateral Awareness

Testing consisted of a series of questions from Piaget (1928) which required the child to show his awareness of right and left on his body, the body of the examiner, and among objects. The resultant scores were the number of errors made. A complete listing of the questions appears in Appendix A.

Speech-Brain Laterality

Dichotic listening was used as an estimate of speech-brain laterality. The equipment consisted of a Tandberg stereophonic tape recorder and a set of Koss (model Pro 4) stereo head phones. Twenty trials of digits were administered. Each trial consisted of 4 pairs of different numbers, with each pair delivered simultaneously at the

rate of one pair per one-half second. Five practice trials preceeded the 20 test trials. After 10 test trials the earphones were reversed so as to minimize any differences in the volume level of each track on the tape. The S was asked to recall as many digits as possible after each trial. Scores were computed on the basis of errors of recall. Left-channel errors were subtracted from right-channel errors. Thus, a plus (+) score on this task indicated left-ear superiority. This is contrasted with the other tasks in which a plus (+) score indicated right-sided superiority. In addition, ratios of the discrepancy between left- and right-channels to the total number of errors were computed.

VIQ

The Wechsler Intelligence Scale for Children was used as a measure of VIQ. An abbreviated form developed by Satz, Van De Riet, and Mogel (1967) was employed. This abbreviated form has the advantage of sampling items from each of the subjects and thus represents the wide range of skills tapped by the standard WISC.

Method of Analysis

Two major types of analyses of the data were computed, taking advantage of the matched design. These included analysis of variance of mean data and Chi-square analyses of frequency data. Two analysis of variance designs were used, the first based on ages (9, 10, 11, 12)

and groups (E and C) was applied to all the data with the exception of those measures which were expressed as frequencies. The second analysis of variance was based on groups, ages and left and right performance on manual dexterity, manual strength and dichotic listening.

The Chi-square analyses was computed on data which could be expressed only in frequencies (tests for controlling eye, self-classified manual preference, and family history of left-handedness). In addition, the Chi-square analysis was applied to the results of the dichotic listening test for additional elaboration of the data.

RESULTS

Analyses of Laterality Measures

Laterality with its many dimensions was the major focus of this study. Therefore, to determine the laterality effect for the experimental (E) and control (C) groups, and for ages (9, 10, 11, 12), analyses were carried out on the following major categories: (1) sensorimotor: manual laterality; (2) sensorimotor: visual laterality; and, (3) cognitive-perceptual laterality. Each of these categories was divided into various subcategories which will be presented below. Analysis of variance summaries on all variables will be found in Appendix C.

Sensorimotor: Manual Laterality

The dependent measures subsumed under sensorimotor: manual laterality include the following (the first four listed in order of increasing complexity): (1) self-classified manual preference, (2) manual preference performance, (3) manual strength, (4) manual dexterity, and, (5) familial history of manual preference. All variables were analyzed to determine any differences in degree of manual asymmetry (laterality) between the experimental and control groups and between the different ages.

Self-Classified Manual Preference

The first and simplest measure of manual laterality, was manual preference. The score was based on a frequency count of the S's verbal statements as to their manual preference. The results, presented in Table 2, show

TABLE 2

SELF-CLASSIFIED HANDEDNESS

Group	Reported Right	Reported Left
E	35	5
C	33	7

that a Chi-square analysis did not reveal a significant relationship between stated handedness and membership in either group (X^2=.39, df 1; p .05).

Manual Preference Performance

A second measure of manual laterality, manual preference performance, was experimentally assessed by ten behavioral tasks. The analyses to determine the difference between the two groups was computed on a discrepancy (asymmetry) score which was based on the right minus left performance. Thus, a plus score indicated right manual preference superiority. A two groups (E, C) by four ages (9, 10, 11, 12) analysis of variance was used to analyze these scores, but revealed no significant differences by group (F=.25, df 1,72; p .05), by age (F=.17, df 3,72; p .05), or age-group interaction (F=.73, df 3,72; p .05).

Manual Strength

Another measure of manual laterality was manual strength, as measured by the Jaymar dynamometer. Again discrepancy (asymmetry) scores were computed subtracting left from right performance and a two groups by four ages analysis of variance was applied to the data. The only result reaching statistical significance was the interaction based on groups and ages (F=3.32, df 3,72; p .05). A clearer view of this interaction can be seen by inspecting the means in Table 3. The interaction primarily reflects the 11-year-old experimental Ss who showed lower mean strength performance than the experimental 10-year-olds, while the reverse was true for the control Ss.[1] Thus, this result did

[1]Tukey multiple range test (Snedecor, 1956) indicated that neither these four cell means nor any of the others differed reliably from each other.

TABLE 3

GROUP AND AGE MEANS FOR STRENGTH DISCREPANCY SCORES

Group	Ages			
	9	10	11	12
E	+1.07	+1.50	-1.58	-0.50
C	+1.37	-2.30	+4.60	-0.76

not suggest that degree of manual laterality was a group or age function.

Manual Dexterity

Manual dexterity represents a more complex measure of manual performance and was assessed by the finger tapping test. Discrepancy (asymmetry) scores were computed on the difference score between right and left hands (R-L). These discrepancy scores were also analyzed in a two groups by four ages analysis of variance. As can be seen in Table B_1, in Appendix B, there were no effects for groups (F=.03, df 1,72; p>.05), ages (F=.15, df 3,72; p>.05) or group-age interaction (F=1.03, df 3,72; p>.05). These results are consistent with the previous analyses which suggest that the degree of manual laterality did not vary as a function of groups or ages.

Familial Manual Preference

A final variable related to manual laterality was the incidence of left-handedness in the immediate families of the subjects (familial sinistrality). A Chi-square analysis of the frequency data was computed to determine whether the attributes of familial sinistrality and treatment groups (E, C) were independent. Inspection of Table 4 revealed no relationship between the two variables (X^2=1.00, df 1; p>.05).

In summary, the results of the discrepancy or asymmetry data were essentially negative for each of the five tests of manual laterality across each of the groups or ages. The experimental group did not show a higher incidence of left-sided manual preference, familial sinistrality, nor were the discrepancy (asymmetry) scores between hands smaller in this group relative to the normal controls.

TABLE 4

HISTORY OF FAMILIAL LEFT-HANDEDNESS

Group	Hand Preference	
	Left	Right
E	9	31
C	13	27

Sensorimotor: Visual Laterality

The measures of visual laterality (macular) were divided into two groups: (1) monocular tasks (sighting); and (2) binocular tasks (proximal and distal). Analyses were performed to determine differences in visual laterality between the experimental and control groups.

Monocular Tasks

Three sighting tasks were used to determine visual laterality in this sample. Again, discrepancy scores were utilized, computed by subtracting left-eye performance from right. A groups by ages analysis of variance was applied to the data and no differences were found for groups (F=2.11, df 1,72; $p > .05$), ages (F=.61, df 3,72; $p > .05$), or group-age interaction (F=.55, df 3,72; $p > .05$) for the visual laterality measures.

Binocular Tasks

The proximal measure of visual laterality was the hole-in-the mirror test. The results of this test are expressed in a frequency count of left or right; however, a relationship was not found between lateral performance on this task and group membership (χ^2=1, df 1; $p > .05$).

The distal and more complex measure of visual laterality was computed on telebinocular scores (a frequency count of right eye, left eye, or neither). The results of this task, as can be seen in Table 5 showed that there were more experimental Ss without a controlling eye than in the normal controls (χ^2=6.67, df 1; $p < .01$). Thus, it was found that only

TABLE 5

INCIDENCE OF NONCONTROLLING EYE

Group	Eye	
	R or L	None
E	25	15
C	35	5

when controlling eye was used as a measure of macular visual laterality that the experimental Ss showed a higher frequency of incomplete lateral performance.

Cognitive-Perceptual Laterality

Four measures of laterality were analyzed under the category of cognitive-perceptual laterality: (1) speech-brain laterality, (2) lateral awareness, (3) finger differentiation, and (4) verbal intelligence. Analyses were carried out to determine group or age differences for these variables.

Speech-Brain Laterality

Dichotic listening was used to provide some indirect information on probable speech-brain laterality. Ss were requested to recall digits which were presented in simultaneous pairs to each ear. In this analysis right channel superiority (superior recall for digits presented to right ear) was believed to be predictive of contralateral left-brain speech laterality, and left channel superiority (superior recall for digits presented to left ear) was predictive of contralateral right-brain speech laterality. The results of a group by ages by channel analysis of variance revealed data consistent with previous research on adult populations (Kimura, 1961; Satz, Achenbach, & Fennell, 1967). Recall was superior for digits, presented to the right ear (i.e., predicted left-brain speech laterality) for both groups ($F=58.11$, df 1,72; $p<.01$).

In addition, discrepancy (asymmetry)scores were computed by subtracting left channel errors from right channel errors. Thus, negative scores indicated a superior recall for digits presented to

the right ear (right channel superiority). It should be remembered that in previous discrepancy computations a minus score referred to left-sided superiority. A group by ages analysis of variance was applied to the discrepancy scores and the one significant result was a group by ages interaction ($F=2.76$, df 3,72; $p<.05$). The data suggested that the result was due largely to the high degree of right channel superiority for the experimental 10 year olds over the 11 year olds, while the opposite was true for the controls. For a clearer view of the data see the means in Table 6.[2]

The final analysis of the dichotic listening test was based on frequency data on the number of Ss. Exact frequencies are shown in Table 7 and reveal that the incidence of left channel superiority was higher in the experimental group ($\chi^2=5.54$, df 1; $p<.025$). This finding is of interest in that the control group had a higher number of self-classified left handers which could have increased the probability of left channel superiority in these Ss. Yet the reverse pattern occurred.

Lateral Awareness

The Piaget schedule was employed as a measure of lateral awareness and the analyses were based on number of errors. A group by ages analysis of variance revealed a significant main effect for groups ($F=7.66$, df 1.72; $p<.01$). These results indicate that experimental Ss exhibited more errors in their knowledge of left and right than did the

[2]Tukey multiple range tests revealed that none of the cell means were significantly different from each other.

TABLE 6

GROUP AND AGE MEANS FOR DICHOTIC LISTENING DISCREPANCY SCORES

Group	Ages			
	9	10	11	12
E	-12.80	-22.40	- 6.70	-12.90
C	-18.50	- 8.80	-27.30	-18.70

TABLE 7

DICHOTIC LISTENING TEST
RIGHT AND LEFT CHANNEL SUPERIORITY

Group	Channel	
	Right	Left
E	29	11
C	37	3

controls. However, it was found that there were not statistically reliable differences by ages (F=1.40, df 3,72; $p > .05$). For a summary of the results on lateral awareness, see Figure 1 and Table B_2 in Appendix B.

Finger Differentiation

The Kinsbourne and Warrington tests of finger differentiation were used as a measure of finger differentiation. As with lateral awareness, analyses were based upon number of errors. A group by ages analysis of variance, as illustrated in Figure 2, resulted in reliable group differences (F=8.34, df 1,72; $p < .01$). These data indicate that the retarded readers made more errors in finger differentiation than did the normal readers.[3] (See also Table B_3 in Appendix B.) This analysis, however, did not reveal an effect by age (F=.78, df 3,72, $p > .05$).

Verbal Intelligence

VIQ, as measured by the WISC, was used to determine the level of verbal intelligence. Verbal intelligence was considered to be a measure of laterality due to the fact that it has been well documented that verbal behavior is represented asymetrically in the brain (Roberts, 1964; Branch, et al., 1964;

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[3]Further analyses were carried out on the four subtests of Kinsbourne and Warrington, Tukey multiple range test revealed that children in both groups made fewer errors on Test 1 than on (a) Test 2 (p .01); (b) Test 3 (p .05); and (c)Test 4 (p .01). See Appendix D for summary figures on these subtests.

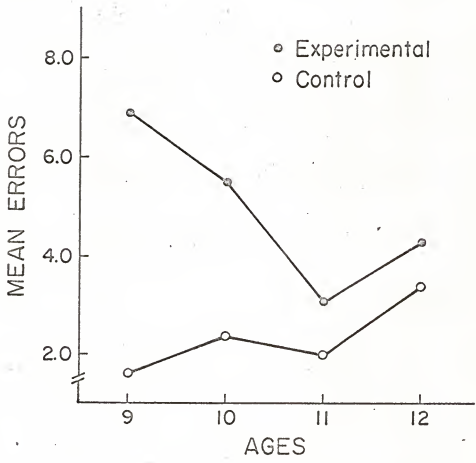

Fig. 1 Errors on Lateral Awareness (Piaget)

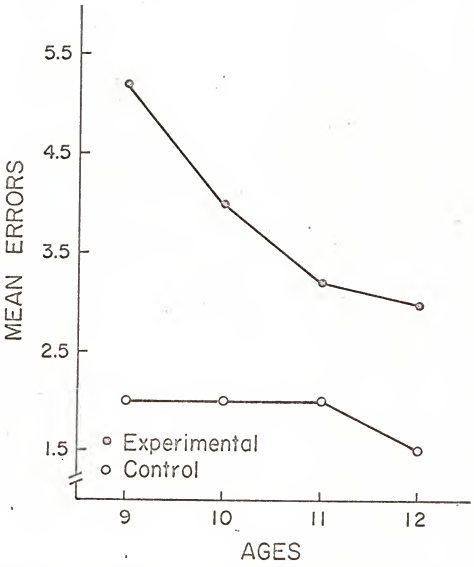

Fig. 2 Errors on Finger Differentiation

Brain, 1965). Moreover, unilateral lesions in the left hemisphere in man have often been associated with alteration of verbal test intelligence (Satz, Daniels, & Richards, 1967). A group by age analysis of variance revealed a significant main effect for groups. The experimental Ss revealed a lower level of VIQ than did the control Ss (F=17.43, df 1,72; $p < .001$). However, there was no difference as a function of age (F=2.30, df 3,72; $p > .05$). For a summary of the VIQ data see Figure 3.

In summary, none of the sensorimotor: manual laterality measures differentiated between the experimental and control groups, and on the visual laterality measures, only the telebinocular data did so. However, on the perceptual-cognitive laterality data, all measures differentiated between the two groups to some degree. Thus, the experimental Ss exhibited a higher frequency of superior recall for information presented to the left ear (right speech-brain laterality), more errors on lateral awareness and finger differentiation, and lower VIQ.

General Level of Sensorimotor and Cognitive-Perceptual Performance

The purpose of this portion of the Results section was to examine some of the non-lateralized aspects of the sensorimotor: manual measures (manual strength and manual dexterity, R + L) and cognitive-perceptual measures (dichotic listening test). Analyses were performed to determine if there were group or age differences on total performance (R + L), rather than on discrepancy (laterality) performance.

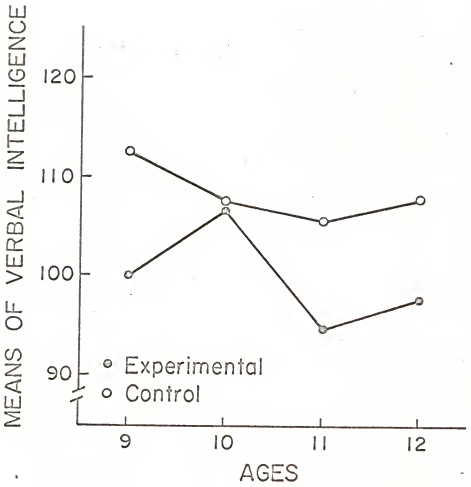

Fig. 3 Verbal I.Q Scores

Sensorimotor: Manual Measures

The two tasks analyzed under this category were manual strength and manual dexterity. The data consisted of right plus left total for both measures.

Manual Strength

A total score of right plus left was used as a measure of manual strength. A groups by ages by total score analysis of variance was performed. Although there were no reliable differences for groups ($F=.06$, df 3,72; $p>.05$), the analysis revealed a difference for ages ($F=16.50$, df 3,72; $p<.001$). Thus, both groups exhibited progressively increasing strength scores with increasing age.[4] See Figure 4 for a summary of means on R & L strength scores.

Manual Dexterity

Total scores on finger tapping computed by adding right and left scores was used as a measure of manual dexterity. A groups by ages by hand performance analysis of variance was applied to the data. A significant main effect was found for groups ($F=6.25$, df 1.72; $p<.05$) and also for ages ($F=3.78$, df 3,72; $p<.05$). Inspection of Figure 5 reveals that the experimental group demonstrated lower tapping scores suggesting a lower overall level of manual dexterity. However, overall manual dexterity (R + L) increased as a function of age for both groups as was found for the strength of grip scores.[5]

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[4] Tukey multiple range tests indicated 12 year olds had significantly higher strength scores than all other groups.

[5] Tukey multiple range tests indicated that 12 year olds differed significantly from 9 year olds.

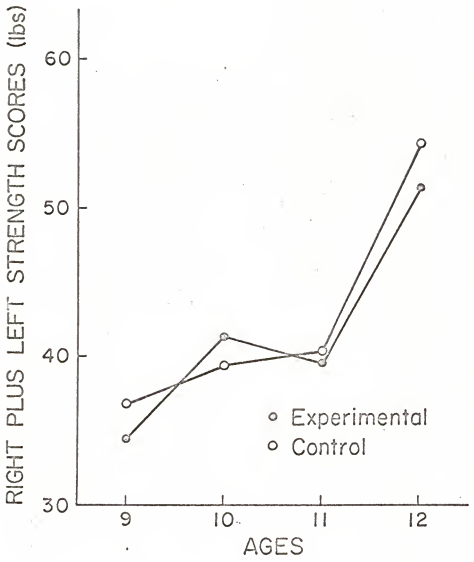

Fig. 4 Total Strength Scores

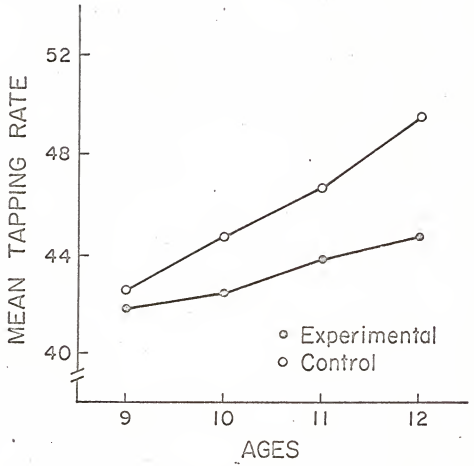

Fig. 5 Total Tapping Scores

Cognitive-Perceptual Measures

The general level measure for dichotic listening consisted of right channel errors plus left channel errors. Thus, the higher the score, the lower the performance. The results of a group by age by channel analysis of variance revealed a main effect for ages which approached significance ($F=2.65$, df 3,72; $p<.06$). The data showed that error recall decreased progressively with increasing ages for the total sample. The data, presented for each group separately, appear in Figure 6 and Table B4 in Appendix B.

In summary, when general levels of performance were analyzed, several differences were found. The only group difference observed was associated with the lower measure of dexterity (finger tapping) for the experimental group. Age differences, however, were found for all three measures: manual strength, manual dexterity, and dichotic listening. In each case, overall performance improved progressively with age.

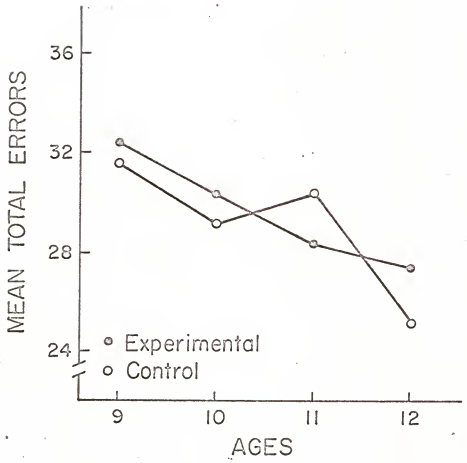

Fig. 6 Total Errors on Dichotic Listening

DISCUSSION

A neuropsychological approach to reading disability, with major emphasis on laterality, has been the focus of this study. This investigation of the differences in the manifestations of laterality between retarded and normal readers yielded both positive and negative findings. With the exception of the higher incidence of non-controlling eye in the experimental group, the sensorimotor results (manual laterality, visual laterality) were negative. However, all the perceptual-cognitive measures of laterality (lateral awareness, finger differentiation, and language asymmetry) differentiated between the two groups. The experimental Ss exhibited a higher frequency of superior recall for information presented to the left ear (right speech-brain laterality), more errors on lateral awareness and finger differentiation, and lower VIQ.

Although several laterality measures differentiated between the experimental and control groups, there were no age differences. Neither the discrepancy scores (dexterity, strength, dichotic listening, vision), controlling eye data, nor VIQ showed age effects. Age effects were found on total tapping scores, total strength scores, and number of errors on dichotic listening. On these tasks, overall performance improved with age. A nonsignificant trend toward improved performance with age was found on lateral awareness and finger differentiation.

Although VIQ did not vary with age, there was a gradual decrement in PIQ as age increased ($F=3.91$, df 3,72; $p < .05$). Since the subjects were matched in PIQ, there were no group differences. In the higher grades, however, there were progressively fewer children who fell within the PIQ range of high normal and above. This datum suggests the possibility that the reading problem, with its accompanying verbal deficits was affecting overall intellectual performance, as the children progressed through school, reflecting the pervasive and debilitating effect of reading problems. That is, regardless of the antecedent causes of reading disability, in time the effect of this disability may produce additional deficits.

Alternatively, the cross-sectional nature of this sample might account for the PIQ differences with age. Since the subjects were not studied longitudinally, the lower PIQs in the older children could have been due to sampling error.

In view of the combination of positive and negative findings, what can be said about the relationship between these variables and the "learning to read" process? Since previous investigators were criticized for their failure to integrate their findings and to relate them to brain maturation and function, it seems necessary for this investigator to do so. An adequate formulation should include the relationship of the laterality variables to each other, to the brain, and to the reading process.

Although reading is a complex process, there is general agreement about some of the basic abilities a child must develop for reading acquisition. Of the variables investigated here, spatial awareness,

lateral awareness, and verbal skills have been shown to be necessary in reading (Palmer, 1964; Eisenberg, 1966; Money, 1966). Thus, deficits in these areas should often result in some degree of retardation in reading.

Since these abilities are assumed to have the common factor of lateralization, perhaps the lateralization process is an etiological factor in reading deficits. It seems germane, therefore, to examine the laterality variables as they are seen in the normal child.

Generally, lateralization refers to the representation or control of a function primarily by one cerebral hemisphere. The measures of particular interest in this study are thought to be lateralized in the left hemisphere.

Semmes et al. (1960) suggested that language specialization (lateralization) stems from basic sensorimotor functions preceding the lateralization of speech. Lateralization of motor functions stabilizes first, followed by sensory and language functions respectively. The lateralization process begins, then, with manual tasks which become differentiated between four to six year of age. Manual laterality is followed by finger differentiation (somatosensory), which stabilizes from six to eight years of age. At eight to ten years, lateral awareness should stabilize. Finally, speech (language) differentiation is achieved between nine and thirteen years (Benton, 1962; Kinsbourne & Warrington, 1963; Palmer, 1964; Belmont & Birch, 1965; and Lenneberg, 1967). This normal hierarchal development of laterality suggests a mechanism underlying reading problems: a delay of lateralization, beginning with the earliest level (motor development), could result

in the retardation of lateralization in all subsequent higher functions. This developmental lag would prevent the child from learning to read at normal age levels.

The present data partially support this theoretical position. The experimental children differed from the controls, showing deficits on all perceptual-cognitive variables as well as controlling eye. It is suggested that these deficits represent a delay in the lateralization of these functions.

When visual laterality was measured by sighting, children in both groups across all age levels had established visual preference. However, in terms of controlling eye, the behavior is more complex and is established at a later level. Whereas in sighting, only one eye is used, there is a rivalry of eyes in binocular vision with one eye controlling and the other assisting (Berner & Berner, 1953; Walls, 1951). The resolution of this rivalry takes place considerably later than sighting and may reflect higher-order aspects of lateralization. Therefore, the higher proportion of experimental children who exhibited no controlling eye lends support for hypothesizing a lag in their lateralization.

Finger differentiation represented the lowest perceptual-cognitive level. This somatosensory and spatial measure differentiated clearly between the two groups. As was seen in Figure 2, the control subjects, at all ages, made virtually no errors on this task. The experimental Ss, however, made many errors, and errors tended to decrease as age increased. These data suggest that the experimental Ss were developing the type of somesthetic lateralization postulated

by Semmes (1968). It would appear that until the lateralization of sensory reception had been completed, the subjects would have difficulty in the interpretation of incoming sensory cues.

Lateral awareness represented a later ontological development. Here again, there were profound differences between the two groups, with the experimental group exhibiting many more errors. Lateral awareness involves a combination of concrete and abstract operations as well as language abilities. One might hypothesize that a relatively high degree of lateralization and differentiation would be necessary in order to master lateral awareness.

The verbal tasks subsumed under WAIS VIQ and dichotic listening were postulated to represent the highest levels of ontological development. If one can assume that degree of language lateralization may be a determining factor in adequacy of verbal skills, then it is consistent to conclude that the lower VIQs of the experimental group reflect delay in lateralization of these functions.

Dichotic listening was the second measure of cerebral lateralization of speech. The results of the analysis were more difficult to interpret developmentally due to the complete absence of data on performance of young children on this task. Although there were no significant group or age differences in degree of asymmetry, nevertheless, more experimental children exhibited left-channel superiority (or contralateral right-brain speech representation). A possible explaination is that if speech is more diffusely represented in younger children and more lateralized in older children, one might expect a higher frequency of left-channel superiority in young children and

in children who are maturationally delayed. More work is needed on dichotic listening, particularly in children, before we have an adequate understanding of normal and abnormal patterns.

In summary, the experimental group exhibited deficits in visual laterality, finger differentiation, lateral awareness, and verbal intelligence. Similarly, the experimental children were shown to have a higher frequency of left-channel superiority on the dichotic listening task, which may point to more diffuse representation of speech, or at least to greater participation of those areas in the right cerebral hemisphere.

However, the experimental Ss did not differ from the controls on manual laterality. Although this discrepancy might negate a developmental lag, the time schedule suggested by Semmes (1968) and Benton (1962) for the normal development of manual lateralization (four to six years) allows for the possibility that the experimental Ss were retarded in their manual lateralization. By the age of nine (the youngest age investigated) the delay was no longer apparent. Therefore, the negative findings on manual laterality are not necessarily inconsistent with a developmental hypothesis. Thus, the data from this investigation partially support the hypothesis that a delay in lateralization contributes to retarded reading.

The fact that no differences were found between the groups in the familial history of left-handedness is not surprising in the light of the present hypothesis. If reading problems are the result of a lag in lateralization of the cerebral hemispheres, then one need not expect a higher incidence of familial sinistrality in the problem group. This

study did not find a relationship between left-handedness (in the Ss or their families) and reading problems. Indeed, the hypothesis presented in this study would not predict such a relationship. Since left-handedness has been frequently associated with reading problems, it was allowed to vary as a dependent measure in the present investigation. In addition, even if incomplete manual laterality were indeed a factor, most family members would have exceeded the age when such lateralization becomes stable.

It was found that the experimental group also exhibited lower total tapping scores than the controls and, thus, were generally less manually dextrous across all age groups. A possible explanation is the influence of manual laterality on manual dexterity. Dexterity is a behavior which develops gradually with increasing age. As seen in Figure 5, all groups and ages were still in the process of developing manual dexterity. It is possible that the experimental children who seemed generally slow in lateralization of higher functions, were also delayed in manual lateralization. This lag could have influenced the general dexterity, resulting in a decrement in overall performance.

Although the previous discussion has supported the theory with developmental evidence, there is another body of evidence that relates the laterality variables to each other, to language behavior and to left-hemispheric function. Such evidence comes from symptomatology found in some brain-injured adults. Although one must be wary about generalizing from acquired deficits to delays in maturation, nonetheless, adults who subsequently suffer insults to the brain might provide insight into mechanisms which influence lateralization. For example,

disease of the left hemisphere in man has frequently been associated with a pattern of deficits involving right-left confusion, dyscalculia (calculation), dysgraphia (writing and spelling), finger agnosia (finger differentiation), constructional apraxia (form perception) and interference with verbal intelligence. Many of these symptoms are found in retarded readers. The first four deficits were thought by Gertsmann (1930) to form a unitary syndrome due to a localized lesion in the region of the left angular gyrus. Although recent research has not upheld the classification of the Gerstmann signs as a unitary syndrome, nor the localizing value of these signs, these particular deficits, along with constructional apraxia, dyslexia, and depressed verbal intelligence, have been found to be associated with left-hemispheric involvement (Heimberger, De Meyer, & Reitan, 1964). Heimberger et al. (1964) and Poeck and Orgass (1967) have observed that this symptom cluster never occurs without aphasia. Thus, with non-focal left-hemispheric lesions, symptoms are found which show a marked similarity to those found in retarded readers. Is there some aspect of left-hemispheric function that responds similarly during maturation or with injury? Although the answer is not yet available, the left hemisphere seems implicated as the source of the symptoms, both acquired and developmental.

Based on the preceding discussion, laterality can be defined as the representation or control of functions by one cerebral hemisphere (for reading-related behaviors, almost always the left hemisphere). It is hypothesized that a developmental lag in the process of lateralization, across all modalities, frequently results in deficits which

interfers with learning to read.

This theoretical formulation suggests a framework for future research on the relationship between reading and laterality. Presently the data is insufficient, particularly concerning manual preference, the earliest function to lateralize. The most powerful research would be a longitudinal study similar to that of de Hirsch, Jansky, and Langford (1966). Very young children, preferably from two to three years of age, should be studied to determine how normal lateralization develops. Sufficient numbers of children must be included so that there will be a population of retarded readers among the group when they eventually learn to read. For example, de Hirsch et al. (1966) studied 54 children and two years later found only eight retarded readers. As a result, they found it unwise to generalize from their data to other children with reading problems. Nevertheless, the longitudinal approach can provide a more definitive understanding of the role of development and maturation in the "learning to read" process. Such a study should investigate many indices of motor, sensory, and perceptual-cognitive lateralization.

An additional approach to the problem would be an electrophysiological study of laterality in young children. Goff, Rozner, and Allison (1962), in the evoked potential recordings of normal adults, have shown the importance of the left hemisphere in somesthetic receptivity. The same phenomenon should be investigated in young children. Similar evoked potential studies could be carried out in other modalities.

Additional information is needed concerning the role of language and verbal abilities among retarded readers. A problem in

this study was the use of VIQ as a measure of the degree of speech lateralization. VIQ has been the best discriminator between normal and retarded readers in both this and other studies (Belmont & Birch, 1966); yet it is uncertain what factors it reflects. Although this investigator believes that speech lateralization affects VIQ, it is certainly one of many factors. Verbal intelligence is a complex ability which is affected by motivation, environmental stimulation, social class, etc. A measure uncontaminated by nonconstitutional variables is needed. In addition, since reading is a verbally loaded skill, it is uncertain how much the lack of speech lateralization affects reading and how much reading problems result in depressed verbal skills. Perhaps a linguistically oriented verbal task, based on structure rather than content, would reflect the maturational more than the cultural aspects of language development.

SUMMARY AND CONCLUSIONS

The differences between retarded and normal readers in the manifestations of laterality were investigated by a number of laterality tasks. Subjects were nonclinic boys of normal intelligence from suburban schools. They ranged in age from nine to twelve years. Each experimental subject was matched with a control on age, sex, race, PIQ and social class. The administered tasks included tests of manual laterality, visual laterality, and perceptual-cognitive laterality. The perceptual-cognitive measures were lateral awareness, finger differentiation, verbal IQ, and dichotic listening. The retarded readers differed from the normal readers on all perceptual-cognitive measures and in the incidence of noncontrolling eye. The retarded readers had poorer performance on lateral awareness, finger differentiation, and verbal intelligence. They also showed a higher incidence of both noncontrolling eye and left-ear superiority (right speech-brain) than did the normal readers. There were no differences between the groups on manual laterality. There were no age effects for any of the laterality measures. There were, however, age differences for overall manual dexterity, manual strength, and errors on the dichotic listening test, with performance improving with increasing age. There were no differences in the incidence of self-classified left-handedness between the groups or their families.

Laterality was defined as representation or control of functions

by one cerebral hemisphere (for reading-related behaviors, almost always the left-hemisphere). The aspects of laterality were seen as representing a hierarchal development of laterality. It was hypothesized that a developmental lag in the process of lateralization, across all modalities, frequently results in deficits which interfer with learning to read.

APPENDICES

APPENDIX A

Right-Left Awareness Items (Piaget, 1928)

1. Show me your right hand._____ Now show me your left hand._____
Show me your right leg._____ Now show me your left leg._____

2. (E sits opposite S) Show me my right hand._____ Now my left._____
Show me my right leg._____ Now my left leg._____

3. (Place coin on table left of a pencil in relation to S.) Is the pencil to the right or to the left?_____ And the penny, is it to the right or to the left?_____ (Have S go around to the opposite side of table and repeat questions.) Is the pencil to the right or to the left?_____ And the penny, is it to the right or to the left?_____

4. (S is opposite E; E has a coin in right hand and a bracelet (or watch) on left arm.) You see this penny. Have I got it in my right hand or in my left?_____ And the bracelet, is it on my right arm or my left?_____

5. (S is opposite three objects in a row: a pencil to the left, a key in the middle, and a coin to the right.) Is the pencil to the left or to the right of the key?_____ Is the pencil to the left or to the right of the penny?_____ Is the key to the left or to the right of the penny?_____ Is the key to the left or to the right of the pencil?_____ Is the penny to the left or to the right of the pencil?_____ Is the penny to the left or to the right of the key?_____

6. (S is opposite three objects in a row: a key to the left, a piece of paper in middle, and a pencil to the right. The following instructions are given to S: "Listen carefully, I am going to show you three things for a very little while. You must look at them very carefully, and then afterwards tell me from memory how the things are arranged. Ready." The three objects were presented to S for 30 seconds and then covered, and he was then asked the following questions.) Is the key to the left or the right of the piece of paper?_____ Is the key to the left or the right of the pencil?_____ Is the paper to the left or the right of the key?_____ Is the paper to the left or the right of the pencil?_____ Is the pencil to the left or the right of the key?_____
Is the pencil to the left or the right of the paper?_____

APPENDIX B

TABLE B_1

MEAN DISCREPANCY SCORES
MANUAL DEXTERITY

Group	Ages			
	9	10	11	12
E	3.94	5.25	1.95	3.28
C	3.54	2.59	4.24	4.69

TABLE B_2

MEAN ERRORS ON LATERAL AWARENESS

GROUP	AGES			
	9	10	11	12
E	6.9	5.5	3.0	4.3
C	1.8	2.4	2.0	3.4

TABLE B_3

MEAN ERRORS ON FINGER DIFFERENTIATION

Group	Ages			
	9	10	11	12
E	5.2	4.0	3.2	2.9
C	2.0	2.0	2.0	1.5

TABLE B_4

MEAN ERROR ON DICHOTIC LISTENING

Group	Ages			
	9	10	11	12
E	32.50	30.95	28.55	27.75
C	31.70	29.40	30.30	25.25

APPENDIX C

ANALYSIS OF VARIANCE FOR MANUAL PREFERENCE PERFORMANCE DISCREPANCY SCORES

Source	SS	df	MS	F
Groups	78.13	1	7.81	0.25
Ages	15.84	3	5.28	0.17
Groups x Ages	67.84	3	22.61	0.73
Error	2226.50	72	30.92	

ANALYSIS OF VARIANCE FOR MANUAL STRENGTH DISCREPANCY SCORES

Source	SS	df	MS	F
Groups	732.05	1	732.05	0.29
Ages	7205.80	3	2401.93	0.93
Groups x Ages	25662.95	3	8554.31	3.33*
Error	185070.20	72	2570.42	

*$p < .05$

ANALYSIS OF VARIANCE FOR MANUAL DEXTERITY
DISCREPANCY SCORES

Source	SS	df	MS	F
Groups	68.45	1	68.45	0.03
Ages	1056.45	3	352.15	0.15
Groups x Ages	7311.45	3	2437.15	1.03
Error	170331.60	72	2365.71	

ANALYSIS OF VARIANCE FOR SIGHTING TASKS
DISCREPANCY SCORES

Source	SS	df	MS	F
Groups	14.45	1	14.45	2.11
Ages	12.55	3	4.18	0.61
Groups x Ages	11.35	3	3.78	0.55
Error	493.20	72	6.85	

ANALYSIS OF VARIANCE FOR FINGER DIFFERENTIATION

Source	SS	df	MS	F
Groups	76.05	1	76.05	8.34**
Ages	21.40	3	7.13	0.78
Groups x Ages	12.15	3	4.05	0.44
Error	656.66	72	9.12	

**$p < .01$

ANALYSIS OF VARIANCE FOR LATERAL AWARENESS

Source	SS	df	MS	F
Groups	183.01	1	183.01	7.66**
Ages	1003.38	3	33.45	1.40
Groups x Ages	44.14	3	14.71	0.62
Error	1719.90	72	23.89	

**$p < .01$

ANALYSIS OF VARIANCE FOR DICHOTIC LISTENING DISCREPANCY SCORES

Source	SS	df	MS	F
Groups	427.81	1	427.81	1.20
Ages	26.44	3	8.81	0.03
Groups x Ages	2949.43	3	983.15	2.76*
Error	25661.30	72	356.40	

*$p < .05$

ANALYSIS OF VARIANCE FOR VIQ

Source	SS	df	MS	F
Groups	15.05	1	1505.11	17.43**
Ages	596.84	3	198.95	2.30
Groups x Ages	405.64	3	135.21	1.57
Error	6217.30	72	86.35	

**$p < .01$

ANALYSIS OF VARIANCE FOR PIQ

Source	SS	df	MS	F
Groups	143.11	1	143.11	2.58
Ages	650.63	3	216.88	3.92*
Groups x Ages	80.83	3	26.95	0.49
Error	3986.90	72	55.37	

*$p < .05$

ANALYSIS OF VARIANCE FOR MANUAL STRENGTH
R & L

Source	SS	df	MS	F
Between Ss				
Groups	84180.62	1	84180.62	0.06
Ages	68924210.00	3	22974740.00	16.50***
Groups X Ages	1879667.00	3	626555.60	0.45
Error (b)	100231400.00	72	1392103.00	
Within Ss				
R+L	266505.60	1	266505.60	2.11
(R+L) x Groups	455.63	1	455.63	0.003
(R+L) x Ages	716821.90	3	238940.60	1.89
(R+L) x Groups x Ages	595581.90	3	198527.30	1.15
Error (w)	9109985.00	72	126527.60	

***$p < .001$

ANALYSIS OF VARIANCE FOR MANUAL DEXTERITY
R & L

Source	SS	df	MS	F
Between Subjects				
Groups	31080.63	1	31080.63	6.52*
Ages	54063.73	3	18021.24	3.78*
Groups x Ages	10200.52	3	3400.18	0.71
Error (b)	343065.00	72	4764.80	
Within Subjects				
R+L	50197.23	1	50197.23	40.28**
(R+L) x Groups	13.22	1	13.22	0.01
(R+L) x Ages	449.03	3	149.68	0.12
(R+L) x Groups x Ages	3685.43	3	1228.48	0.98
Error (w)	89707.10	72	1245.93	

*$p < .05$

**$p < .01$

ANALYSIS OF VARIANCE FOR DICHOTIC LISTENING
R & L

Source	SS	df	MS	F
Between Ss				
Groups	2402.50	1	2402.50	0.29
Ages	64845.00	3	21615.00	2.65+
Groups x Ages	9952.50	3	3317.50	0.40
Error (b)	586360.00	72	8143.89	
Within Ss				
R+L	1004890.00	1	1004890.00	58.11***
(R+L) x Groups	16402.50	1	16402.50	0.94
(R+L) x Ages	1405.00	3	468.33	0.02
(R+L) x Groups X Ages	126482.50	3	42160.83	2.43
Error (w)	1245020.00	72	17291.94	

+$p < .06$

***$p < .001$

APPENDIX D

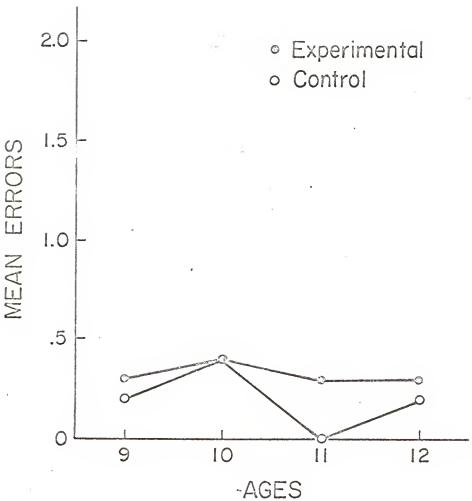

Fig. 7 Kinsbourne - Test I

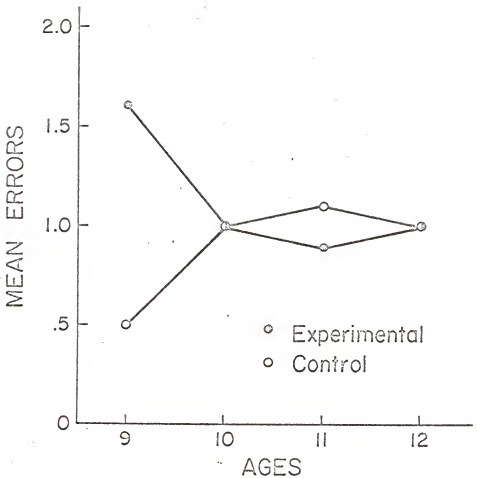

Fig. 8 Kinsbourne – Test 2

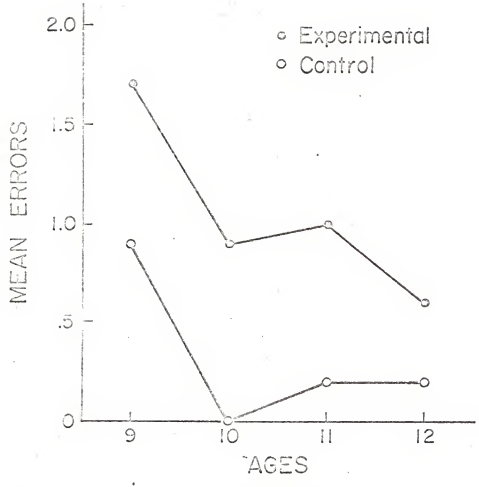

Fig. 9 Kinsbourne – Test 3

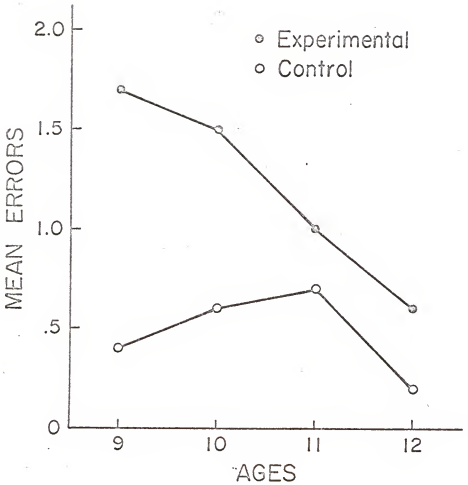

Fig. 10 Kinsbourne – Test 4

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BIOGRAPHICAL SKETCH

Sara Stelle Sparrow was born May 9, 1933, in Minneapolis, Minnesota. In June, 1958, she was graduated, summa cum laude from Montclair State College, Montclair, New Jersey, with a major in speech. From 1958 to 1961 she was a speech therapist for the Orange County School System, Orlando, Florida. In 1961 she received her Master of Arts in speech pathology from the University of Florida. From 1962 to 1964 she was coordinator of speech therapy for the Orange County Schools. From 1964 until the present she has been pursuing her degree of Doctor of Philosophy. She completed an internship at the University of Florida and the West Haven Veterans Administration Hospital, West Haven, Connecticut. Since January, 1968, she has been an associate in research at Yale University. She is a member of the American Psychological Association and the American Speech and Hearing Association.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1968

E. Clifton Jones
Dean, College of Arts and Sciences

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